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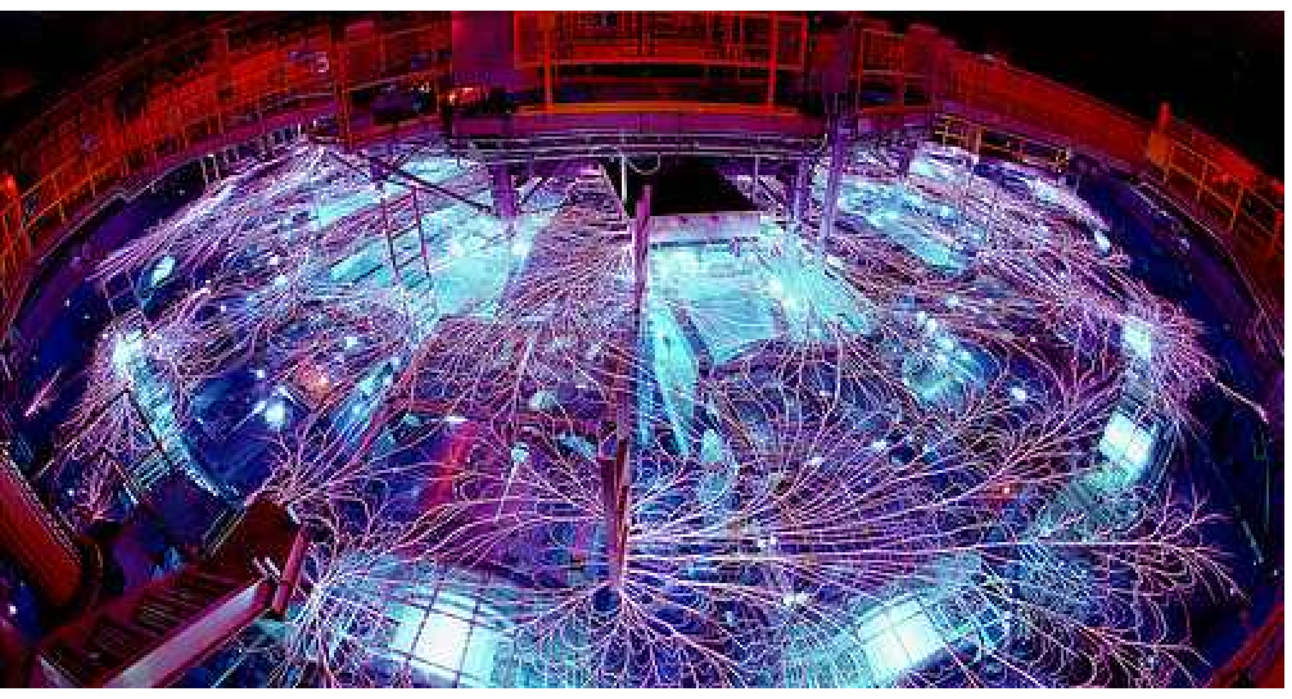

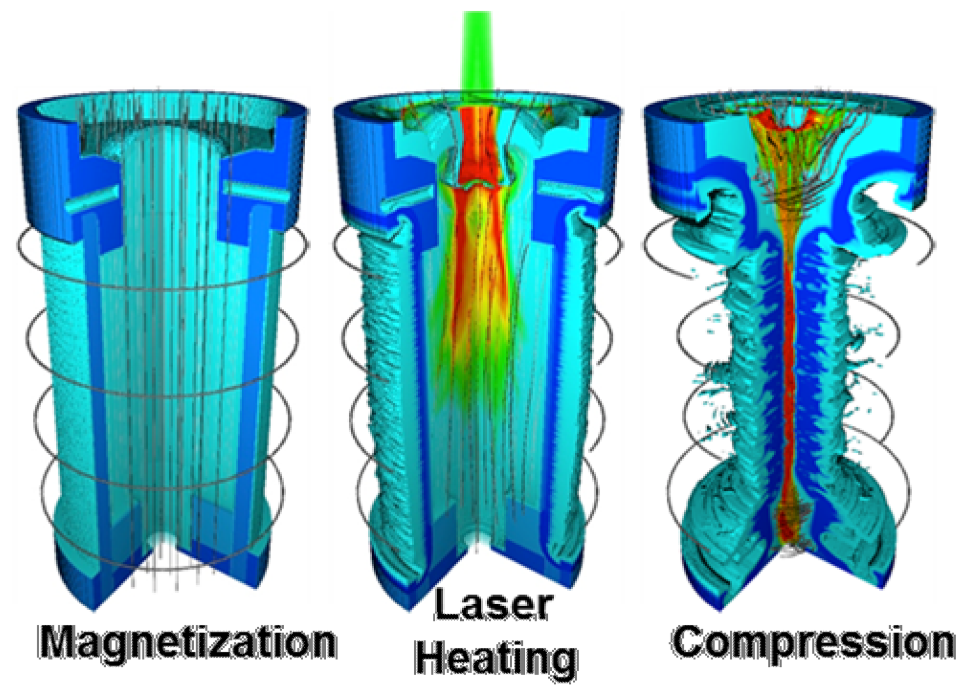

Adding a long-pulse mode option to Z-Petawatt for improved MagLIF performance

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Introduction

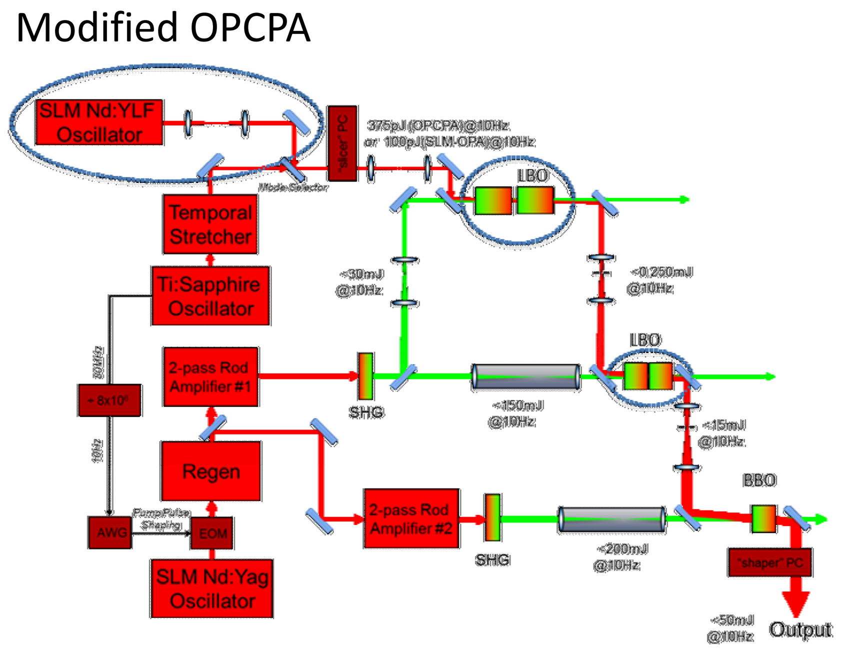
Magnetized **L**iner **I**nertial **F**usion (MagLIF) is an approach for thermonuclear fusion that is driven by the Z-Machine, which can channel more than 20 MA of drive current into a deuterium filled beryllium liner. The resulting magnetic pressure implodes the liner and compresses a laser pre-heated (by Z-Beamlet at 2kJ/0.2-4ns/527nm) fuel, while a 10 T axial magnetic field is used to reduce heat losses.

Laser heating is achieved by shooting ZBL through a 1.7-3.5 μm thick polyimide window. In order to minimize the plethora of resulting laser plasma instabilities (LPI), we currently use a pre-pulse to disassemble the window while keeping the main laser intensity below LPI thresholds. Presently, we are fundamentally limited with ZBL to 4 ns main laser pulsewidth and a 0.5 ns, 200 J pre-pulse at 3.5 ns separation. In order to overcome these limitations, we have modified Z-Petawatt (ZPW) to operate in either short (ps) or long-pulse (ns) mode. In long pulse mode, a kJ class ZPW beam can be co-injected (i.e. co-bored) and frequency doubled to 225 J (demonstrated) along the same ZBL beamline which allows us to:

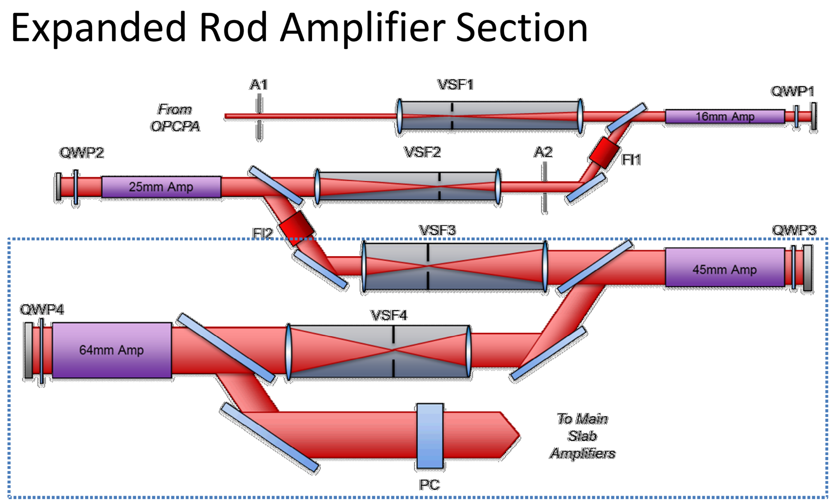
- generate a pre-pulse with arbitrary time separation which should give the window more time to dismantle and increase the main beam transmission,
- use the ZPW energy to add to the ZBL main pulse for improved fuel heating,
- use long pulse ZPW for backlighting of a MagLIF experiment.

Laser Upgrades

Modified OPCPA

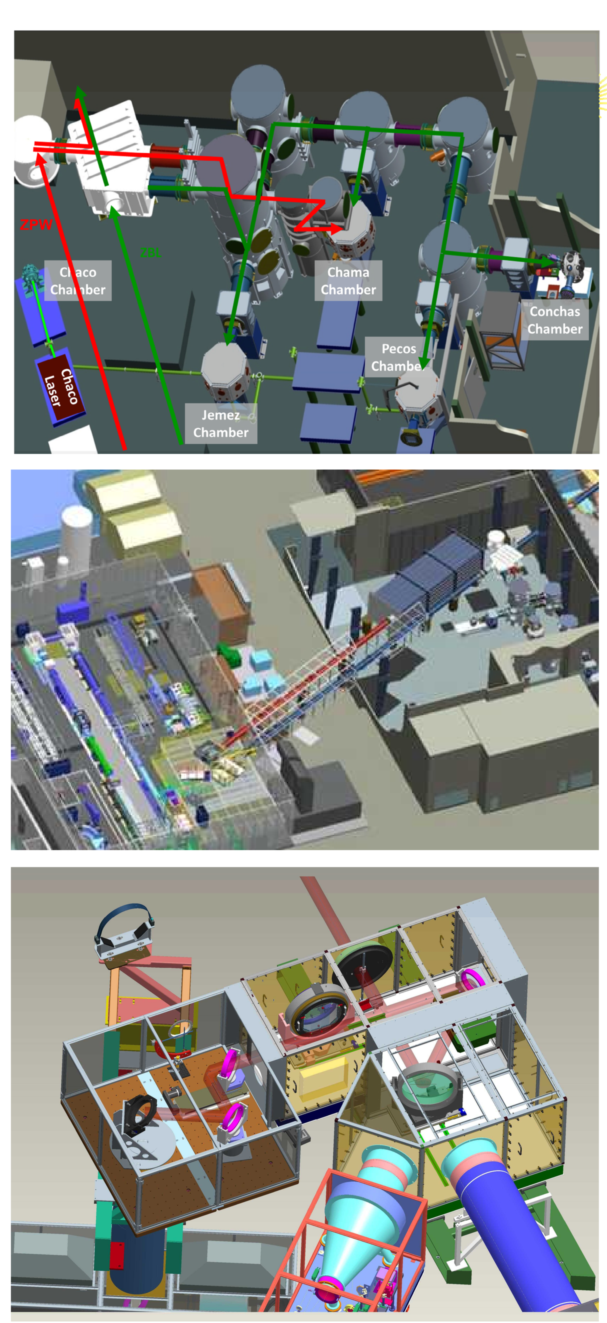


Expanded Rod Amplifier Section



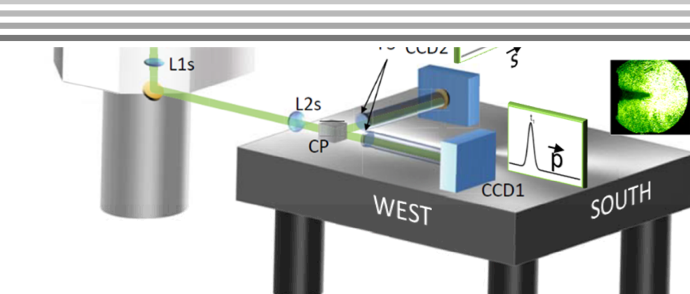
Note: Dashed lines depict additions and/or improvements

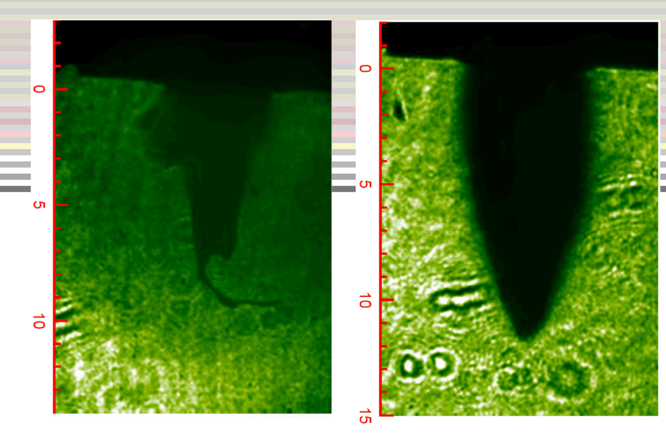
Co-Injection



Improved Energy Deposition in D_2 Fuel

We performed dedicated experiments to evaluate the improvements stemming from a co-injected pre-pulse at t=-20ns versus the "standard pulse" at t=-3.5ns.

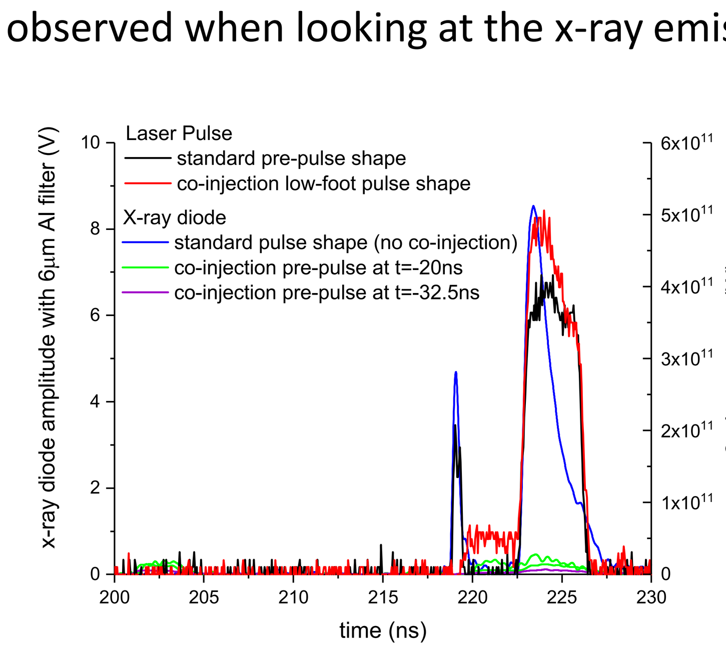


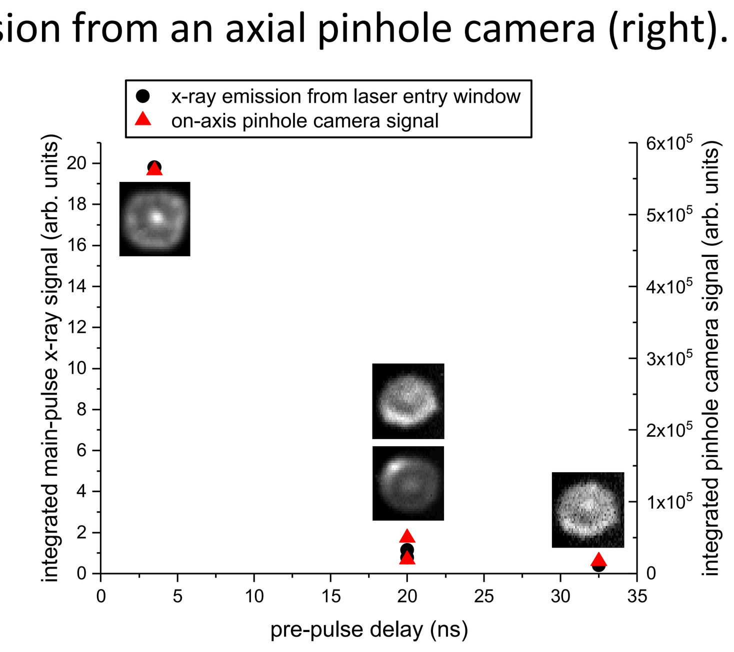


(left) Experimental setup measuring the spatio-temporal plasma evolution, when D_2 is heated by ZBL in various pre-pulse configurations. Front surface x-ray emission and SBS back-scatter are measured but not shown in this layout. (right) Shadowgraph of the laser heated plasma for a ZBL pulse and co-injection plus ZBL pulse-shape.

Reduced Main Pulse Absorption at Laser Window

The figure below (left) depicts the ZBL laser power at the laser entry window and its associated x-ray signature, stemming from the laser window interaction. One can see, that the "standard pulse" shape results in two rather large x-ray bursts, indicating strong plasma absorption in the entry window. On the other hand, a 20J, 2 ns FWHM pre-pulse at -20 ns resulted in a main pulse x-ray reduction of 20x and a delay of 32.5 ns decreased the x-ray emission by 40x ! A similar trend is observed when looking at the x-ray emission from an axial pinhole camera (right).

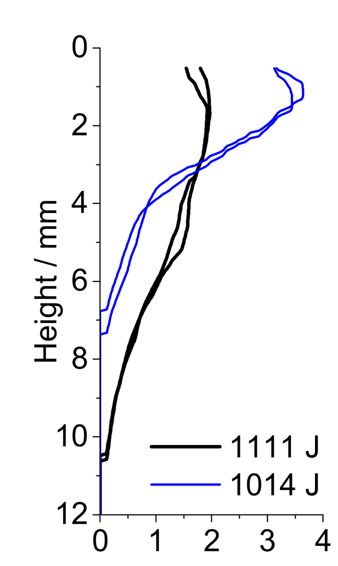


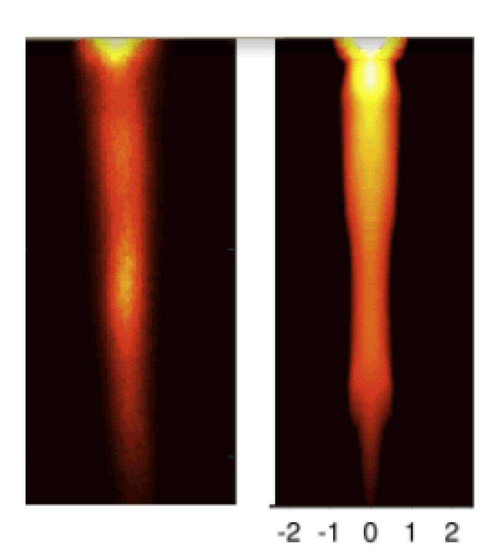


Better Agreement between Theory and Simulation

Graph: Deposited laser energy versus plasma penetration depth. (blue) no co-injection, (black) co-injection

X-ray images: Measured co-injection plus ZBL x-ray emission from a side on pinhole camera (left), as well as the simulated counterpart (right).





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